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*Mines Branch Program
on Environmental Improvement*

MINES BRANCH PROGRAM ON ENVIRONMENTAL IMPROVEMENT

compiled by
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Contents

Foreword	
1. Introduction	1
2. The Problem of Air Pollution	2
3. Air Pollutants Production in Canada	2
4. The Problem of Water Pollution	8
5. Role of the Mines Branch in Environmental Improvement	8
Appendix A - Current Projects	10
Appendix B - Mines Branch Environmental Improvement Capabilities	13
Appendix C - Proposed Projects	17

Foreword

During the Sixties, Canada's mineral industry doubled its production rate to give a 1969 total value of \$4.7 billion of which metallic minerals account for \$2.3 billion and mineral fuels \$1.5 billion. In all, the industry now produces about sixty different minerals, employs a labour force of 150,000, and contributes \$3.4 billion to Canada's export trade.

The continuing high standard of living enjoyed by Canadians is a direct result of Canada's high rate of industrial growth. Unfortunately, under the present scheme of things, affluence and industrialization are inseparable from urbanization and pollution. For example, some 60 per cent of Canada's population resides in highly industrialized urban areas where the greatest variety and largest concentration of man-made pollutants are released to the surrounding environment. The by-products of the combustion of fuels and the smelting of ores, such as smoke, soot and fumes and waste solutions from mineral beneficiation, hydrometallurgical and mining operations have been widely condemned for their ugliness, nuisance and cost. We need to bear in mind the comparison of the earth to a spaceship in which man must carry all his needs and live with all his waste products. It is within this closed-system context that we must consider our pollution problems.

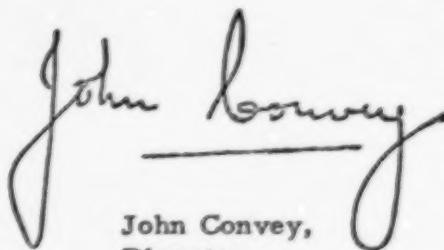
In 1968 Canada produced over 304 million tons of air pollutants including both respirable and non-respirable sizes of metallic and hydrocarbon particulates and gaseous oxides of sulphur, nitrogen and carbon. Carbon dioxide accounted for about 97 per cent of the total. With the continuing high rate of industrial growth, these pollutant emissions will be increased to more than 350 million tons in 1970. More alarmingly, projections indicate that the 1968 rate will be doubled by 1980 and quadrupled by 2000.

The problems are not simple and will not be solved by using more scrubbers or higher smokestacks, for example. New technology must be developed not only to control gaseous pollutants but also to prevent their formation at all by removal prior to combustion. The Mines Branch has been concerned for a number of years with reaching practical and constructive solutions to certain aspects of the air pollution problem. Its various research projects related to mine environment, burning of fossil fuels, and smelting of sulphide ores have recently been integrated into its Program on Environmental Improvement.

Although the air pollution problem is a major one of immediate and urgent concern, the Canadian mining and metallurgical industry must

also concern itself with its responsibilities relating to water and land pollution. Heavy metals and undesirable compounds, introduced by ore treatment waste solutions, tailings pond overflows and mine waters are a source of water pollution. The industry must, therefore, search for methods to minimize this contribution to environmental degradation. The Mines Branch is concerning itself with this aspect of water pollution and has projects now underway related to this problem. Undoubtedly, this phase of the Mines Branch Environmental Improvement Program will expand.

This report summarizes the principal air pollutants, estimates their current and future magnitudes, and the current activities and capabilities of the Mines Branch for scientific and technical investigations in the overall area of environmental improvement. We believe that through this program the Mines Branch can make a significant contribution to solving Canada's increasingly difficult environmental problems.

A handwritten signature in cursive script, reading "John Convey". The signature is written in dark ink and is positioned above a horizontal line.

John Convey,
Director.

Mines Branch Program on Environmental Improvement

1. Introduction

The predicted increases in energy requirements for Canada, both short and longer term, emphasise that certain environmental problems need immediate attention and will require very much more in the future. Thus, although effective devices for controlling some forms of air pollution have been developed, there are other problems that remain unresolved. Additional research and development is needed to devise economic methods for adequate control of particulate and gaseous air pollution from sulphur dioxides, oxides of nitrogen, and incompletely burned hydrocarbons.

In addition, although we can reasonably expect further technological improvements for controlling air pollution to be developed in the future, it would be prudent to assume that such developments will only keep abreast of the increasing burden of pollutants in the atmosphere unless better controls at the source can be obtained. That is, the most promising means for improving air quality lies in preventing the emission of pollutants in the first place.

Preventing the pollution of our waters is also a responsibility of the Canadian mining and metallurgical industry. Sulphuric acid and significant concentrations of metals can occur in mine drainage waters and tailing-pond overflows. Trace amounts of reagents are present in the water with flotation tailing slurries. Hydrometallurgical operations by their nature are a potential source of water-soluble pollutants. It is likely that hydrometallurgical methods will be used increasingly as alternatives to those smelting operations now causing serious air-pollution problems. These and similar water-pollution problems must be faced.

The primary objectives of the Mines Branch, in contributing to the solution of these vital national problems, are to determine the nature and amount of pollutants being released to the environment and to carry out scientific and engineering R&D of acceptable control measures where warranted in order to meet the four basic requirements of the environment:

- (a) Insuring the elements of simple survival
- (b) Preventing disease and poisoning
- (c) Maintaining an environment suited to man's efficient performance
- (d) Preserving comfort and the enjoyment of life.

With public attention being focussed on environmental pollution, the Branch is intensifying and integrating its anti-pollution efforts. Its programs, all concerned with minerals-related pollution, are aimed at characterizing pollutants at the source, removing them by physical or chemical means as much as possible, and disposing of the waste materials by converting them to saleable products or by such methods as incineration, impoundment, or dispersion by carefully designed stacks.

2. The Problem of Air Pollution

Air pollution is mainly due to the combustion of fossil fuels (coal, petroleum, gas) and to the primary and secondary processes in the mineral industries (principally smelting of sulphide ores and the production of steel).

There are two types of pollutants, gases and particulate matter, and these can cause chemical reactions in the atmosphere that produce additional pollutants (e. g. hydrocarbons). Three of the gaseous pollutants (carbon monoxide, nitrogen oxides, and sulphur dioxide) are specifically toxic in excessive quantities. Particulate matter causes soiling and loss of visibility and also carries absorbed gaseous and liquid pollutants into the lungs and onto plant surfaces and buildings. Most of the pollutants either disperse and settle from the air naturally or are eventually washed from the atmosphere by rain.

Carbon monoxide and hydrocarbons result from the incomplete combustion of all fossil fuels. Nitrogen oxides result from all high-temperature fuel-burning processes, but particularly from internal combustion engines. Sulphur dioxide is produced by fuel combustion and the smelting of sulphide ores. Carbon dioxide results from the complete combustion of fossil fuels and may have widespread low-level environmental implications.

Fly ash, soot and other liquid or solid particles are produced in combustion either by entrainment of ash and partially burned fuel particles or by formation of organic particles by pyrolysis or synthesis in a furnace.

3. Air Pollutants Production in Canada

Table 1 presents an estimate of the current amount of pollutants being produced in Canada from combustion of fossil fuels and from metallurgical operations. The estimate is based on a

Table 1

Emission of Pollutants from Combustion* and Smelting** Processes in Canada
(millions of tons)

Source	CO ₂	NO	CO	Parti- culates	SO ₂	SO ₃
Domestic fuels	64.6	0.02	0.03	0.04	0.20	0.005
Commercial fuels	77.3	0.60	9.30	6.00	0.10	0.003
Industrial fuels	144.0	0.30	0.07	0.12	1.10	0.03
Smelting					4.80	
Iron and steel				0.22		
Cement and lime	10.0					
Totals	295.9	0.9	9.4	6.4	6.1	0.04

*DBS 1968 fuel consumption statistics

**Estimate by Mineral Resources Branch

number of assumptions, but these are considered to be reasonable and the overall total is believed to be on the conservative side.

In view of the current intense interest in the improvement of the environment, it is reasonable to expect that by 1980 most large industrial cities will have standards to limit the concentration of sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrocarbons, and particulate matter in the atmosphere. Where solid and liquid fuels are used in large amounts in urban areas, cleaning of the effluent gases will probably be required. No current technology can economically remove carbon monoxide, hydrocarbons, and oxides of nitrogen from the gases of stationary combustion sources, although the amounts of carbon monoxide and unburned hydrocarbons in flue gases are reduced by more efficient modern combustion equipment.

Projections have been made to 1980 and 2000 for Canada (base 1966) and for the United States (base 1963) of the ratios of the probable emission quantities of air pollutants and these are shown in Table 2. In addition, the table shows estimated ratios for emissions in the United States assuming the development and application of new technology during the forecast periods. It is obvious that reliance on present technology is quite insufficient for our future needs.

The following conclusions from this table are generally applicable to urban and heavy industrial areas in both Canada and the United States:

Carbon Monoxide and Hydrocarbons - The total of carbon monoxide and hydrocarbons should remain unchanged because of the trend to larger, more efficient units for burning fossil fuels and because of improvements in the internal combustion engine due to present and future regulations to control air pollution.

Oxides of Nitrogen - Because of the trend to larger fossil fuel burning power units and of higher operating temperatures, there is likely to be an increase in oxides of nitrogen since technological improvements for removing these oxides from gas streams will probably lag. Some control will probably be required by the year 2000.

Sulphur Dioxide - Unless the fuels, metallic minerals or effluent gases are treated, the emission of sulphur dioxide is in direct proportion to the total sulphur content of the raw

TABLE 2 - Ratios of estimated quantities of pollutants emitted to the atmosphere

	Applying only present technology (Canada)*		Applying only present technology (USA)**		Applying the technology anticipated to be developed by research & development (USA)	
	1980/1966	2000/1966	1980/1963	2000/1963	1980/1963	2000/1963
Carbon monoxide	1.8	3.6	2	4	1	1
Hydrocarbons	2	4	2	4	1	1
Oxides of nitrogen	2	4	2	4	1.5	1
Sulfur dioxide	1.8	3.5	2.5	5	2	.5
Particulate matter	2.5	5	1.5	2	1.25	1

* Systems Research Group study

** "Energy R & D and National Progress", A.B. Cambel et al, Interdepartmental Energy Study, Supt. of Documents, Washington, D.C., 1964.

fuels and metallic minerals. This will undoubtedly force the pace of R&D and the application of improved techniques for sulphur removal since otherwise an intolerable pollution problem will be created due to the increased use of fossil fuels and to the growth of the Canadian mineral industry, particularly in the light of the new requirement by Ontario for smelting a greater proportion of sulphide concentrates in Canada.

In firing gas, oil and pulverized coal, 95 to 98 per cent of the sulphur in the fuel is converted to sulphur dioxide and about one per cent goes to sulphur trioxide. When coal is fired in a stoker, some of the sulphur reacts with the retained ash and only 60 to 75 per cent is emitted as sulphur oxides.

Some of the methods for sulphur oxides removal are absorption on charcoal or on recirculated fly ash; oxidation on vanadium catalysts; injection of additives such as limestone, calcium oxide, calcium carbonate, gaseous ammonia and dolomite before precipitation; and scrubbing of the flue gas with sodium and ammonium bisulphite solutions. The alternative to removing sulphur from flue gases is removing it prior to burning or smelting.

Carbon Dioxide - In 1960, human beings produced about 1.0×10^9 tons of carbon dioxide and coal and crude oil burning produced about ten times that amount. Since current doubling time for world population is about 30 years and for fossil fuel combustion about 30 years, there is concern since it appears that doubling the carbon dioxide concentration of the atmosphere would cause a rise of from 2.5 to 6.5°F (because CO₂ absorbs infrared and therefore would trap outgoing radiant heat from the earth near the surface). However, the problem does not appear to be alarming since it is estimated that worldwide photosynthesis by plants uses 60×10^9 tons of the carbon dioxide per year. Nevertheless, carefully monitoring of the carbon dioxide content of the atmosphere is essential and sufficiently sensitive measuring instruments must be developed.

Particulate Matter - Because the technology for removing suspended solids from gases is well-developed, and because

of the increase in size and efficiency of fossil-fuel burning plants, it is estimated that by the year 2000 the level of particulate emissions will return to the 1963 levels. These projections may change depending on the rate of construction of nuclear-powered generating stations.

In summary, from Table 2 it is quite evident that the extent of air pollution will increase very significantly within the next twenty to thirty years unless improved technology is developed and applied. Furthermore, the pollution problem must be viewed as a national one whose eventual solution depends on decreasing emission of pollutants at the source.

4. The Problem of Water Pollution

Unlike the situation as it relates to air pollution, there are no detailed data available regarding the types and amounts of water pollutants that can be attributed to Canadian mining and metallurgical operations. However, there is no doubt that significant water pollution is resulting from these operations and the industry is keenly aware of its obligations. Methods now being considered for the control of water pollutants include recirculation of plant water, neutralization of waste solutions with subsequent recovery of precipitated solids, and ion exchange methods. The actual application of these and other methods requires a considerable development effort in order to achieve the desired results at minimum cost.

In addition to the water pollution resulting from mining operations, many other manufacturing operations can cause the pollution of our waters with metals. An example of this is mercury contamination from certain plants. It is conceivable that the metallurgists with his background in the recovery of metals from solution may have to assist these other industries with their problems.

5. Role of the Mines Branch in Environmental Improvement

Although provincial air pollution programs have the primary responsibility for controlling pollutants emissions from stationary sources, this responsibility is being supplemented by direct federal technical assistance in providing expertise and guidance. Thus, the National Research Council is proposing to establish a national committee for the primary purpose of preparing and publishing a unified set of recommended standards including air criteria for environmental quality in Canada. NRC is also proposing to set up a national documentation and information centre on pollution under the

National Science Library.

The increasing effort that will be necessary to control environmental pollution will require the federal government to provide the provinces and industry with more scientific and technical knowledge in the form of new and improved methods for pollutant control. The Mines Branch possesses unique capabilities in this respect because of its experienced staff and special facilities developed over the years for investigating fuel combustion, mineral extraction, and mineral and metal processing.

Most large fossil fuel-burning plants for generating electricity are located in metropolitan areas that are also subject to many other sources of air pollution. In its Environmental Improvement Program the Mines Branch is investigating the removal of impurities from coal and oil prior to its combustion, neutralization of potential pollutants during combustion, more efficient combustion techniques, and more effective dispersion, by means of tall stacks, of the gases formed during combustion. The list of current abatement projects (Appendix A) indicates the emphasis placed by the Branch on coal and oil pollution problems. Removal of impurities prior to combustion is particularly attractive since secondary pollution control measures are thereby made less costly and more effective.

Aside from the fuels research, the Mines Branch in its investigations over the years in mineral and metal extraction and processing gained considerable knowledge on various aspects of heat and dust-emitting processes including the hazard of pollution. In mining research, the Branch conducts projects that are concerned with safety and health at the stringent standards required for underground mines in regard to respirable and explosive dust and purity of mine air. Thus, in the various laboratories of the Branch there has accumulated a considerable body of data related to the quality of the atmosphere and of the water which can provide the basis for development and management of our air and water resources in the industrial and habitation environment. Appendix B contains a listing of Mines Branch capabilities in the field of environmental improvement.

The list of proposed projects (Appendix C) indicates the additional technical contributions this Branch is prepared to make to the conservation of Canada's environment, provided sufficient additional funds are made available.

We believe that the Mines Branch Environmental Program constitutes a good example of the wise application of science and technology for the attainment of national goals relevant to Canadian society.

Appendix A - Current Projects

Title	Staff (FTE)		Budget 1970-71	
	Prof.	Tech.	Operating	Capital
1. Characterization of combustion source pollution in a research tunnel furnace.	1.0	1.75	\$35,500	20,000
2. Dispersion of pollutants from tall stacks by aerial probing.	0.4	0.25	9,000	20,000
3. Development of blue-flame burners for liquid fuels.	0.25	0.50	8,500	1,000
4. Consulting services to industry, government agencies, consultants and universities.	1.0	-	14,000	-
5. Fixation, degradation and collection of pollutants before emission to atmosphere.	1.0	1.0	23,000	-
6. Combustion performance testing of government heating plants.	0.25	0.20	6,000	-
7. Development of air pollution methodologies.	0.25	0.15	4,400	5,500
8. Fuel and fuel additive evaluation.	0.50	0.50	12,000	3,000
9. Incineration of industrial wastes.	0.25	0.50	8,000	1,500
10. Noise pollution from combustion processes.	0.20	0.15	2,200	300
11. Comparative dust measurements.	0.3	0.7	12,000	2,000
12. Dust from Canadian rocks.	0.7	1.1	22,000	2,500

Appendix A - Current Projects (cont'd)

Title	Staff (FTE)		Budget 1970-71	
	Prof.	Tech.	Operating	Capital
13. Clean-up of mine air.	1.1	0.9	38,250	4,250
14. Calibration of laboratory and field equipment.	0.2	0.1	5,500	6,000
15. Re-use of milling plant waters.	1.0	-	12,000	-
16. The investigation and evaluation of by-product synthetic gypsum.	0.5	0.5	10,000	2,000
17. Iron oxide precipitator dust as a component of structural clay products.	0.2	0.2	5,000.	3,000
18. Dry separation methods for potash ores.	0.2	0.2	5,000	3,000
19. Reduction of atmospheric pollution in the treatment of non-ferrous alloys.	1.4	1.4	38,300	2,500
20. Fumeless refining of steel.	0.5	1.0	19,250	26,000
21. Treatment of mine and metallurgical plant liquid effluents by known technology and developing new technology.	2.0	2.0	71,800	2,900
22. Application of chlorine metallurgy in sulphide ore treatment to produce sulphur instead of sulphur dioxide	2.0	2.0	71,800	2,900
(a) Production of reactions in metal-sulphur-oxygen-chlorine systems	1.0	1.0	35,900	1,400
(b) Application of hydrometallurgical-chloride processes.				

Appendix A - Current Projects (cont'd)

Title	Staff (FTE)		Budget 1970-71	
	Prof.	Tech.	Operating	Capital
23. Development of sulphur dioxide absorbents	2.0	1.0	71,800	2,900
24. Sources and control of arsine in hydrometallurgical plants treating arsenic-bearing ores.	1.0	1.0	35,900	1,400
Totals	19.2	18.1	577,100	114,050

Note

The above project costs do not include the costs of the necessary extensive supporting analytical services that include polarography, atomic absorption, spectrography, X-ray analysis, etc. Although these costs have not been estimated, they are significant. Overhead costs have not been included in the above table.

Mines Branch Environmental Improvement Capabilities1. Apply contemporary research and technology

1.1. Efficient operation of all heat, mineral, metallurgical, coke and mining processes

- 1.1.1. domestic and industrial fuel burning
- 1.1.2. federal heating plants
- 1.1.3. ferrous and non-ferrous smelters
- 1.1.4. cupolas
- 1.1.5. coke ovens
- 1.1.6. crushing and ore milling

1.2. Gas scrubbing technology

- 1.2.1. mechanical, low-resistance separators
- 1.2.2. mechanical, high-resistance, cyclone separators
- 1.2.3. electrostatic precipitators
- 1.2.4. bag filters
- 1.2.5. water scrubbers
- 1.2.6. water cyclone scrubbers
- 1.2.7. chemical scrubbers (NaOH for HCL as example)

1.3. After burners

- 1.3.1. coke ovens
- 1.3.2. smelters
- 1.3.3. refinery flames
- 1.3.4. cupolas
- 1.3.5. incinerators
 - municipal
 - industrial wastes
 - special (pesticides, insecticides, herbicides)

1.4. Improved fuels

- 1.4.1. fuel additives
- 1.4.2. pyrite separation from coal
- 1.4.3. pyrolysis of coal
- 1.4.4. hydrogenation of oil

1.5. Sample pollutant emission - toxic and non-toxic

- 1.5.1. particulates +0.5 μ
- 1.5.2. fumes -0.5 μ
- 1.5.3. gases
- 1.5.4. noise

- 1.6. Analysis of pollutant emissions - qualitative and quantitative
 - 1.6.1. particulates
 - 1.6.2. fumes
 - 1.6.3. gases
 - 1.6.4. water contamination in form of petroleum products
 - 1.6.5. soil contamination
- 1.7. Modify proprietary fuel burner designs
 - 1.7.1. federal heating plants
 - 1.7.2. industrial burners
 - 1.7.3. domestic (heating) burners
 - 1.7.4. process after-burners
- 1.8. Apply CCRL chimney height standard to ensure adequate dispersion of hot dust and gas plumes
2. Develop new methods of pollution abatement and control through research (air and water)
 - 2.1. Characterize pollutant emissions
 - 2.1.1. fuel combustion in relation to aerodynamics and thermodynamics of flames
 - 2.1.2. incineration
 - (a) municipal waste
 - (b) industrial waste (scrapped auto wastes)
 - (c) special (pesticides, insecticides, herbicides)
 - (d) process fumes, dust and gas clouds
 - 2.1.3. pyrometallurgical processes
 - (a) cupolas
 - (b) reverberatory furnaces
 - (c) Flaven furnace
 - (d) combined shaft-electric furnace
 - 2.1.4. hydrometallurgical processes
 - (a) substitute for chlorine
 - (b) more efficient use of chlorine in separate chamber of process
 - 2.1.5. coke ovens
 - (a) dustless charging
 - (b) continuous coke-forming
 - (c) alloy dust from fine coal-handling

- 2.1.6. oil refining
- 2.1.7. ore crushing - milling, soil handling
- 2.1.8. mineral recovery processes
- 2.2. Rationalize fuel burner designs
 - 2.2.1. aerodynamically
 - 2.2.2. flame recirculation to control nitrogen fixation
 - 2.2.3. flame anchoring (to control pulsations and explosives)
 - 2.2.4. develop (clean) blue flame for domestic heating with oil
 - 2.2.5. develop industrial blue flame (air atomizing—minimize flame pressure drop)
 - 2.2.6. after burners
 - 2.2.7. refinery flames
- 2.3. New and improved fuels
 - 2.3.1. fuel additives
 - 2.3.2. sulphur-free oil
 - 2.3.3. sulphur-free coal
 - 2.3.4. high calorific gas from coal
- 2.4. Improved process operating techniques and designs
 - 2.4.1. thermal power generation
 - 2.4.2. cupolas
 - 2.4.3. melting operations
 - 2.4.4. coke ovens
 - 2.4.5. blast furnaces
 - 2.4.6. open hearth with oxygen burning
 - 2.4.7. B.O.F.
 - 2.4.8. dry quench hot coke-allay dust from fine coal handling
- 2.5. Remove SO_2 , SO_3 , NO_x in dilute phase from flue gases and smelter off-gases
 - 2.5.1. fuel additives
 - 2.5.2. limestone injections
 - 2.5.3. external and internal flame recirculation

- 2.6. Remove SO_2 in concentrated phase from sulphide ore roasting
- 2.7. Environmental control in mines, process plants, special environments
 - 2.7.1. improved filter media
 - 2.7.2. alloy dust - combined oil treatment - water spray
 - 2.7.3. catalysts for auto exhaust after-burners
 - 2.7.4. control injection, detonation, conflagration in explosive atmospheres, mines, etc.
 - 2.7.5. diesel exhaust - reduce $\text{CO-H}_x\text{Cy}$, etc.
- 2.8. New pyrometallurgical processes
 - 2.8.1. Flaven furnace
 - 2.8.2. combined shaft-electric furnace
 - 2.8.3. continuous coke process
- 2.9. New hydrometallurgical processes
 - 2.9.1. substitute for chlorine
 - 2.9.2. increase efficiency of use of chlorine
- 2.10. New pollution sampling and analytical techniques
 - 2.10.1. particulates ($+0.5 \mu$)
 - 2.10.2. fumes (-0.5μ)
 - 2.10.3. gases
 - 2.10.4. petroleum products in water
3. In collaboration with other government departments, establish assimilative capacity of air sheds and atmosphere by helicopter probing
4. Develop ambient air quality objectives

Appendix C - Proposed Projects

Title	Staff (FTE)		Estimated Annual Cost	
	Prof.	Tech.	Operating	Capital
1. Aerodynamic studies of air-fuel mixing	0.75	0.25	\$16,500	3,000
2. Use of tracers to elucidate atmospheric dispersion of pollutants and flow patterns in turbulent diffusion flames	0.50	0.25	13,500	8,000
3. Removal of sulphur dioxide from boiler flue gas.	0.50	0.25	11,500	3,000
4. Continuous sampling of particulate matter in flue gas and plumes.	0.25	0.25	7,500	7,000
5. Diffusional analysis of radon gas emission in uranium mines	1.5	2.0	45,000	5,000
6. Rapid deterioration of silica (alpha-quartz) in mine dusts	1.0	1.0	37,500	2,500
7. Environmental classification of mines	0.5	0.5	20,000	5,000
8. Re-use of milling plant wastes (extension of current project No. 15).	-	0.5	22,000	-
9. Compilation of waste minerals and waste materials from mines, mills, and processing plants	0.3	-	6,000	-
10. Evaluation and utilization of cement dust from stacks and plants	0.2	-	3,000	-

Appendix C - Proposed Projects (cont'd)

Title	Staff (FTE)		Estimated Annual Cost	
	Prof.	Tech.	Operating	Capital
11. Reduction of particulate and gaseous pollutants from cupo'as	1.0	3.0	57,500	107,000
12. Fumeless refining of steel	1.0	2.0	39,500	52,000
13. Application of metal oxide absorbents for sulphur dioxide control, including equipment design and pilot plant investigations	2.0	2.0	71,800	2,900
14. Development of continuous automatically controlled processes for the treatment of mine and metallurgical plant liquid effluents	1.0	1.0	35,900	2,900
Totals	10.5	13.0	387,200	198,300